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Mathematical modeling of non-Fickian mass transport in fractured porous media

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Abstract

The paper provides an introduction to fundamental concepts of mathematical modeling of mass transport in fractured porous heterogeneous rocks. Keeping aside many important factors that can affect mass transport in subsurface, our main concern is the multi-scale character of the rock formation, which is constituted by porous domains dissected by the network of fractures. Taking into account the well documented fact that porous rocks can be considered as a fractal medium and assuming that sizes of pores vary significantly (i.e. have different characteristic scales), the fractional order differential equations that model the anomalous diffusive mass transport in such type of domains are derived and justified analytically. Analytical solutions of some particular problems of sub-diffusion and super-diffusion in the fractal media of various geometries are obtained by the method of Laplace transformations. Extending this approach to more complex situation when diffusion is accompanied by advection, solute transport in a fractured porous medium is modeled by the advection-dispersion equation with fractional time derivative. In the case of confined fractured porous aquifer, accounting for anomalous non-Fickian diffusion in the surrounding rock mass, the adopted approach leads to introduction of an additional fractional time derivative in the equation for solute transport. The closed-form solutions for concentrations in the aquifer and surrounding rocks are obtained for the arbitrary time-dependent source of contamination located in the inlet of the aquifer. Based on these solutions, different regimes of contamination of the aquifers with different physical properties can be readily modeled and analyzed.

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Keywords

Diffusion, Fractal, Fractional derivative, Fracture, Porous medium